TOXIC ELEMENT

Hg

Cd Pb Zn

Ni Cu Cr As

SURVEY

Director

Thomas C. McMahon

Division Of Water Pollution Control

Massachusetts Water Resources Commission

TOXIC ELEMENT SURVEY

PROGRESS REPORT NO. 1

Hg

Cd Pb Zn

Ni Cu Cr As

April, 1972

by

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MASSACHUSETTS WATER RESOURCES COMMISSION
DIVISION OF WATER POLLUTION CONTROL
THOMAS C. McMAHON, DIRECTOR

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FOREWORD

The purpose of this progress report is to make some of the data collected thus far under the Toxic Element Survey available. No attempt has been made to interpret the data in terms of environmental hazards because the significance of data such as contained herein is only beginning to be studied. It is anticipated that by the time this two year survey is completed, data from other related studies will be available for comparison and at least some tentative conclusions on the environmental hazard should be deduceable by then.

River contained mercury concentrations close to the 0.5 ppm guideline established for seafoods. The Department of Natural Resources and the Department of Public Health pooled their capabilities and undertook a comprehensive program to evaluate the levels of mercury in environmental locations in Massachusetts. The intensive survey included examinations of:

I. Drinking Water Supplies

II. Shellfish Harvesting Areas

III. Industrial Wastewaters

IV. River and Estuarine Waters and Sediments

V. Sewage Treatment Digestors

The evaluation of the mercury levels present in the drinking waters of the Commonwealth was the first concern of this cooperative effort. In this phase of the surveillance program over 200 municipal water supplies were examined and found to contain mercury levels well below the U.S. Public Health Service proposed standard of 0.005 ppm. The majority of drinking waters possessed less than 0.0002 ppm mercury and no water sample showed mercury concentration higher than 0.0004 ppm. These results clearly showed that no mercury problem existed in the public water supplies of Massachusetts.

The ability of aquatic life to concentrate mercury from its aquatic environment directed the Division of Environmental Health's attention to the mercury levels in shellfish. In this program, shellfish areas yielding over 98% of the marketable production in the State were sampled and analyzed

for their mercury levels. Two areas open to the taking of shellfish were found to contain levels of mercury in the shellfish in excess of the FDA interim guidelines of 0.5 ppm. These areas are now closed. Subsequent investigation indicated that the use of mercurial anti-fouling paints used on the hulls of boats was the source of heavy metal contamination.

One area of fresh water was recently found to contain some fish which exceed the recommended standard and this is being fully investigated. The Division of Fisheries and Game is continuing its own fresh water fish sampling program to evaluate the mercury problem and they have issued a progress report (3). This effort is being augmented and expanded by the project described herein.

A survey of the Massachusetts industries uncovered six active sources of mercury pollution. Two of these industries stopped using mercury as of January 1, 1971 and the other plants have achieved a 90% reduction with complete phasing out to be effected in approximately six months. Sludge samples from sewage treatment plants were analyzed for mercury and other trace metals to qualitatively determine the amounts of metals being discharged to sewers and to locate systems in which further action and/or investigation might be needed. Sludges were analyzed because metals tend to concentrate in them.

While these data were being collected, a meeting involving the Division of Water Pollution Control, Department of Public Health and Division of Fisheries and Game resulted in a proposal to carry-out a two year in depth survey of various toxic elements in fish, shellfish, sediments and

water of the Commonwealth. Since the program was much too ambitious to be conducted with regular budget funds, the Massachusetts Division of Water Pollution Control, under the authority conferred by Section 38 of the Massachusetts Clean Waters Act, requested that $67,500 of Research and Demonstration Bond Fund money be approved for the proposed project. Funds were approved and the joint sampling program was undertaken. Two laboratory personnel were hired to actually prepare and analyze the samples, and an additional atomic absorption unit (Perkin-Elmer Model 403) was purchased. Analyses are conducted at the Lawrence Experiment Station, Department of Public Health.

Staff members of the Lawrence Experiment Station aid in the processing of the samples and the laboratory aspects of the project are under the immediate supervision of the Director of Research, Lawrence Experiment Station. The Division of Water Pollution Control is responsible for collecting and delivering samples. Additional samples have been provided by the Massachusetts Division of Fisheries and Game, Division of Marine Fisheries, Department of Public Health, the United States Geological Survey, the Woods Hole Oceanographic Institution, and the Marine Biological Laboratory in Woods Hole.

In the period from February 1971 to October 1971, over 500 samples have been analyzed for:

Zinc	Cadmium	Copper	Chromium	Mercury	Nickel
Arsenic	Lead	Volatile Solids			

Most of the samples have been sediment from rivers and marine shellfish. However, water samples, finfish (both marine and freshwater) and fresh water mussels have also been analyzed.

II. Procedures

A) Determination of Trace Metals In Shellfish

1) Preparation of Samples

A sampling of six animals is usually taken to determine the concentrations of trace metals in quahogs, oysters and soft shell clams. Prior to shucking, the animals are placed in tap water and scrubbed with a stiff bristle brush to remove any surface dirt. The animals are then allowed to drain on paper towels.

All the animals from a specific sampling are shucked and the shellfish meats and shell liquor placed in a porcelain dish. Immediately following this operation, the shucked meats and liquor are poured upon a plastic sieve with openings of approximately 2 mm and the meats are spread over the sieve to insure efficient drainage. An oyster sample is allowed to drain for five minutes while quahog and soft shell samples are allowed to drain for two minutes. The drained shellfish meats are then placed in a Waring Blender and the sample homogenized to a uniform color and consistency.

2) Concentration of Mercury in Homogenate

Five grams of homogenated sample are placed into a clean B.O.D. bottle, 10 milliliters of concentrated sulfuric and 10 milliliters of concentrated nitric acid are added and the sample is allowed to digest overnight at room temperature. The

sample is considered completely digested when the solution becomes highly colored with no pieces of undissolved matter, although the solution may be slightly cloudy. Sufficient potassium permanganate solution (4%) is added to the digested sample to maintain a purple color in the mixture for at least thirty minutes. Distilled-demineralized water is added to the oxidized sample to establish a 250 ml volume. A fifty milliliter aliquot sample is transferred to the aeration flask of the flameless atomic absorption apparatus and the excess permanganate is reduced by the addition of 2 ml of a solium chloride-hydroxylamine sulfate solution (12% of each salt). Five milliliters of a stannous sulfate (10% in 0.5 N sulfuric acid) suspension are added and the flask is immediately attached to the aeration train forming a closed system. The circulating pump, which has previously been adjusted to a rate of 1 liter per minute, aerates the samples and volatilizes the mercury as a vapor throughout the enclosed train. The mercury vapor passes through a cell positioned in the light path of the atomic absorption spectrophotometer. Absorbance (peak height) is measured as a function of mercury concentration. The micrograms of mercury are determined from the absorption behavior of standard solutions processed in the same manner. Since the fifty milliliter aliquot sample actually contains one gram

of the original homogenate sample, the microgram per fifty milliliter aliquot sample is synonomous to the milligrams of mercury per kilogram of drained wet weight (ppm).

3) Concentrations of Trace Metals (Cd, Pb, Zn, Cu, Cr & Ni) in Homogenate

Ten grams of a homogenated sample are placed in a porcelain evaporating dish, five milliliters of concentrated nitric acid and approximately 100 ml of distilled demineralized water are added and the sample digested to dryness on a steam bath. This digestion process is repeated two more times. Following digestion, the residue is wetted with 2 ml of concentrated nitric acid and is quantitatively transferred with the aid of distilled-demineralized water and a rubber policeman through a Watman No. 42 filter into a 100 ml Nessler tube and diluted to the mark with distilled-demineralized water. The acid extract is transferred to a clean plastic, screw-cop bottle and labelled as to sample number and metal analyses to be performed. The diluted sample also with an acid blank are analyzed by Atomic Absorption Spectrophotometry using a Perkin-Elmer Model 403. The milligrams of metal per kilogram of drained wet tissue (ppm) are calculated by multiplying the micrograms per milliliter found in the 100 ml acid extract by 10.

B. Determination of Trace Metals and Volatile Solids in Sediment Samples

1) Preparation of Samples

Sediment and core samples are transferred to large evaporating dishes and dried at a low temperature in a hot air oven. The sample is then pulverized and shaken on a No. 30 sieve. All components of the sample that fail to pass this sieve, such as stones, twigs, leaves, etc., are discarded. A representative sample of the material passing the sieve is taken for the following analyses.

2) Concentration of Mercury in Sediment Samples

Five grams of the sample passing the No. 30 sieve are processed in the same manner as the shellfish homogenate. (Refer to Sec. A-2)

3) Concentration of Trace Metals (Cd, Pb, Zn, Cu, Cr & Ni) in Sediment Samples

Ten grams of the sample passing the No. 30 sieve are processed in the same manner as the shellfish homogenate. (Refer to Sec. A-3)

4) Concentration of Arsenic in Sediment Samples

An appropriate sample is weighed and placed into the generator bottle of the Gutzeit apparatus, 50 milliliters of distilled-demineralized water, 5 ml of concentrated hydrochloric acid, 2 ml of potassium iodide (15%) and 0.5 ml of an acidified stannous chloride solution are added successively, with thorough

mixing after each addition. The mixture is allowed to stand for 15 minutes to effect the reduction of arsenic to the trivalent state.

Three grams of zinc are added to the generator bottle and the scrubber-absorber assembly is attached immediately. The scrubber section contains glass wool impregnated with lead acetate solution and 5.0 milliliters of silver diethyldithiocarbamate reagent are present in the absorber tube. The arsine liberated from the sample reacts with the silver salt forming a soluble red complex which is suitable for photometric measurement.

5) Concentration of Volatile Solids in Sediment Samples

Two to three grams of sample passing the No. 30 sieve are transferred to a tarred aluminum dish and weighed to the nearest tenth of a gram on an analytical balance. The sample is ignited in a muffle furnace at 550°C to constant weight. The percent volatile solids is calculated from the loss on ignition.

III. Results

Although statistical analysis of all of the data has not been undertaken, the shellfish data has been analyzed and general conclusions on the other samples can still be made.

A. Shellfish

The ability of shellfish to accumulate detectable concentrations of heavy metals from their environment has been well documented in

both domestic and foreign literature. In 1969, a program was initiated by the Federal Food and Drug Administration to collect data on the various metals found in shellfish from representative areas on the Atlantic, Pacific and Gulf Coasts of the United States. The following conclusions were drawn from the data that were collected: 1) The concentration of metals in shellfish depends upon the metal concentrations available in the marine environment. 2) The levels of heavy metals in shellfish varied from area to area within the same species. The levels of metals in oysters in the northeast were generally greater than Southern Oysters of the same specie. 3) The levels of the same metal varied from specie to specie. The level of zinc found in the Northern Oyster was over 1000 mg/Kg wet weight while the quahog showed 40 ppm and the surf clam showed 15 ppm.

Based upon the above conclusions, it was considered reasonable to establish separate alert levels for each metal rather than one level for a combination of metals. The alert level concept was developed to be used as a guide or indicator of metal pollution in shellfish growing waters and was not intended to reflect the toxicity of metals contained in shellfish. They were proposed expressly for the sole purpose of acting as indicators of any change in the concentration of trace metals in growing waters. The alert levels established for each trace metal in each shellfish specie are based

on the mean of the data collected during the Federal survey plus one standard deviation.

The alert levels for trace metals in shellfish harvested from various sections of the U.S. were proposed at the 7th National Shellfish Workshop held in Washington, D.C. in 1971. The delegates at this Workshop voted against the proposal and postponed action on establishing alert levels for trace metals in shellfish until the next scheduled Workshop in 1973. The alert levels that were proposed by the Food and Drug Administration for shellfish species harvested from waters in the Northeastern section of the U.S. are presented in the following Table.

	Oyster	Quahog	Soft Shell
Mercury, ppm	0.2	0.2	0.2
Cadmium, ppm	3.5	0.5	0.5
Lead, ppm	2.0	4.0	5.0
Zinc, ppm	2000.0	65.0	30.0
Chromium, ppm	2.0	1.0	5.0
Copper, ppm	175.0	10.0	25.0

A program was established within this Toxic Metal Survey, to investigate the trace metal concentrations present in the shellfish species harvested from Massachusetts coastal waters. The samples of shellfish were collected by field personnel of the Division of Environmental Health. The results obtained from a statistical evaluation of the preliminary findings are presented in the following table.

	Oyster (n=4)		Quahog (n=18)		Soft Shell (n=30)	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Mercury, ppm			0.30	0.21	0.31	1.06
Cadmium, ppm	0.78	0.48	0.26	0.31	0.30	0.33
Lead, ppm	0.29	0.13	1.9	1.2	5.45	8.09
Zinc, ppm	747.	449.	29.	11.	34.3	20.7
Chromium, ppm	.08	.13	1.2	.89	1.96	.77
Copper, ppm	1.31	.92	7.2	4.3	28.8	18.5
Nichel, ppm	0.70	.29	2.2	0.75	3.7	4.7

B) Sewage Sludges

Perhaps what was most striking initially were the high concentrations of elements in both sewage sludges and stream sediments.

The first data to be received was that on the sludges at treatment plants. Twenty-two treatment plants were sampled either one, two or three times. The values varied widely (generally by one to three orders of magnitude) not only between plants but also between the samples taken at the same plant (Table I).

Percent frequency (based on a total of 54 analyses) were plotted for Cadmium, Mercury, Nickel, and Lead. The median (graphical) and the concentrations exceeded by 10% of the samples are on a dry weight basis:

Element	Median	10% of Samples Exceed
Cd	12 ppm	45 ppm
Hg	9.5 ppm	43 ppm
Ni	22 ppm	100 ppm
Pb	425 ppm	1200 ppm

The treatment plants sampled are a cross section of the larger cities and towns in Massachusetts so it is expected that concentration of metals in primary, secondary, and digested sludges from other plants would be similar.

C) <u>Sediment Samples</u>

1. <u>Grab</u>

Sediment samples from both the fresh and salt water domains of the Commonwealth have been analyzed. The maximum, mean, and minimum values for the eight elements are presented in Table II.

Qualitatively, the water bodies from which sediment samples were taken can be divided into four categories based on the volume and strength of the mainly organically rich discharges and the assimilative capacity of the receiving water.

I. Heavily Polluted
   A. Blackstone River
II. Moderately Polluted
   A. North River
III. Lightly Polluted
   A. Boston Harbor (outer)
   B. Quinsigamond River
IV. Relatively Clean
   A. South River
   B. Lake Quinsigamond
   C. Massachusetts Bay

For purposes of comparison, data on identical elements in surficial material from the U.S. Geological Survey (4) are given. The samples were analyzed on the basis of material that was retained on a 200 mesh sieve. Analyses were conducted semiquantitatively by spectrographic analysis. except for zinc for which a colormetric method was employed. These plus additional samples were later analyzed for mercury (5), using an atomic absorption method developed by Vaughn and McCarthy (6). Also, included are two sets of data on the element concentration in crustal rocks (7, 8).

2. Cores

Four cores from Lake Quinsigamond and five from Boston Harbor were taken. Each core was from 18" to 24" in length. Most of the cores were divided into five sections and analyzed for elements and percent of volatile solids (Figure 1).

The three cores from the deeper (35' to 80') stations in Lake Quinsigamond exhibit a decrease in element concentration with depth. It is of interest to note that the percent volatile solids increases with depth; this may be the result of previously deposited organic matter. The fourth core was taken in 15' of water about 20' from a concrete support for an 8" pipe line which crosses the lake at this point. The crossing is at a very narrow (50') neck. The core revealed three distinct sections. The first 10' and the last 4" to

8" were clearly the remains of attached aquatic weeds, which still profliferate in this area. The middle section (about 10" in length) was nearly all sand. It was assumed that this sand resulted from the construction of the pipeline support. The sediment from the three deeper stations was a fine, generally grayish, clay-silt with some black ooze - presumably a typical laccustrine deposit. One striking result was the apparently high content of arsenic throughout the cores. Another was the enrichment of lead, zinc and copper in the upper portion of the cores.

The cores from Boston Harbor demonstrated less distinct trends (Figure 2). In fact, Core #4 exhibits generally increasing concentrations with depth. The concentration of mercury in Boston Harbor samples (both core top and grab) is of interest. Thirteen of the eighteen samples exceeded 1.0 ppm (dry weigt) as shown in Figure 3. Care must be taken in interpretation because it is not known which cores may represent disturbed sediments from, e.g., channel dredging, previous land filling and past dumping for disposal.

Another significant unknown is the relationship between stratigraphy and time for both sets of cores. For instance, the large weed population at Station 6 in Lake Quinsigamond certainly causes debris to accumulate at a much faster rate than the deposition at the deep water stations.

TABLE I

ELEMENT CONCENTRATIONS IN SEWAGE SLUDGES *

MAXIMUM, MINIMUM - mg/kg DRY WEIGHT BASIS

Element	Number of Times Present	Total Range Of all Samples	Greatest Range Among Samples Taken From Same Plant
Hg	54	1,130. 1.65	1,130. 1.65
Cd	54	182. 2.22	182. 3.57
Pb	54	20,000. 3.17	20,000. 6.95
Zn	54	10,500. 144.5	10,500. 91.
Cu	54	5,950. 5.26	3,920. 10.5
Ni	54	75,000. 1.52	75,000. 6.95
Cr	54	1,850. 17.35	1,340. 62.5
As	1	1.98 0.0	1.98 0.0
Ag	54	1,375. 10.7	1,375. 27.75

* Based on a total of 54 analyses from 22 different plants. Two or three samples were collected from all but two plants from which one sample each was analyzed.

TABLE II

CONCENTRATION[1] OF ELEMENTS IN SEDIMENT

MAXIMUM, MEAN, AND MINIMUM

Element	Blackstone	North River	South River	Boston Harbor	Quinsigamond River	Lake Quinsigamond (grab)	Lake Quinsigamond (core)[2]	Lake Quinsigamond[3]	Massachusetts Bay	Surficial Material U.S.A.[4]	Surficial Material Mass.[4]	Crustal Rocks[5]	Crustal Rocks[6]
Mercury	6.40	5.5	0.07	3.2	0.34	7.0	0.62	7.0	1.0	4.6	0.2[7]	--	--
	2.62	1.08	0.05	1.53	0.25	2.68	0.4	1.54	0.41	.11	--	0.5	0.08
	0.52	0.04	0.03	0.64	0.21	0.44	0.23	0.23	0.18	.01	.06	--	--
Cadmium	150.0	5.5	0.3	7.5	0.6	5.5	2.8	5.5	2.0	--	--	--	--
	35.7	1.4	0.3	1.85	0.36	3.05	2.2	2.63	0.38	--	--	0.2	0.2
	2.8	0.0	0.0	0.00	0.3	0.9	1.7	0.9	0.00	--	--	--	--
Lead	980.	300.	50.	200.	120.	400.	250.	400.	44.	700.	17.5	--	--
	336.	104.	26.	74.	52.	265.	213.	239.	14.1	20.	--	16.	12.5
	57.	2.0	10.	7.2	16.	130.	150.	130.	1.0	10.	12.5	--	--
Zinc	4000.	985.	17.	350.	92.	730.	380.	730.	100.	2000.	370.	--	--
	953.	343.	15.	131.	52.	420.	268.	344.	33.4	54.	--	65.	70.
	88.	9.0	11.	11.	28.	130.	190.	130.	8.0	25.	31.	--	--
Nickel	320.	32.	4.2	36.	64.	48.	46.	48.	22.	700.	85.	--	--
	91.	9.6	3.9	19.6	28.4	40.8	36.5	38.7	10.0	20.	--	80.	75.
	16.	2.3	3.3	10.	5.5	23.	27.	23.	1.8	45.	12.5	--	--
Copper	1850.	635.	8.4	180.	21.	180.	88.	180.	52.0	300.	--	--	--
	458.	89.5	6.7	67.9	12.8	104.	68.5	86.5	13.8	25.	--	45.	55.
	50.	1.8	5.8	18.	5.5	46.	54.	46.	9.0	1.	--	--	--
Chromium	900.	363.	7.5	250.	40.	73.	70.	73.	200.	570.	85.	--	--
	276.	57.6	6.2	97.6	18.5	40.5	36.3	38.4	36.4	53.	--	200.	100.
	34.	6.0	4.9	25.	6.7	21.	24.	21.	6.8	1.	22.5	--	--
Arsenic	20.	4.4	0.4	6.0	9.0	94.	64.	94.	--	--	--	--	--
	6.2	1.6	0.2	3.3	4.4	48.5	38.1	43.3	--	--	--	2.	1.8
	0.7	0.0	0.0	2.2	1.6	25.	12.2	12.2	--	--	--	--	--
No. of Samples	13	12	3	18	6	4	4	8	9	863	4	--	--

NOTES ON TABLE II

1. mg/kg (ppm) dry weight basis on material passing a 30 mesh sieve

2. First 3 inch portion of each core for comparison with grab samples

3. Average of grab samples and core top samples

4. See reference (4) for elements other than mercury and reference (5) for mercury

5. See reference (7)

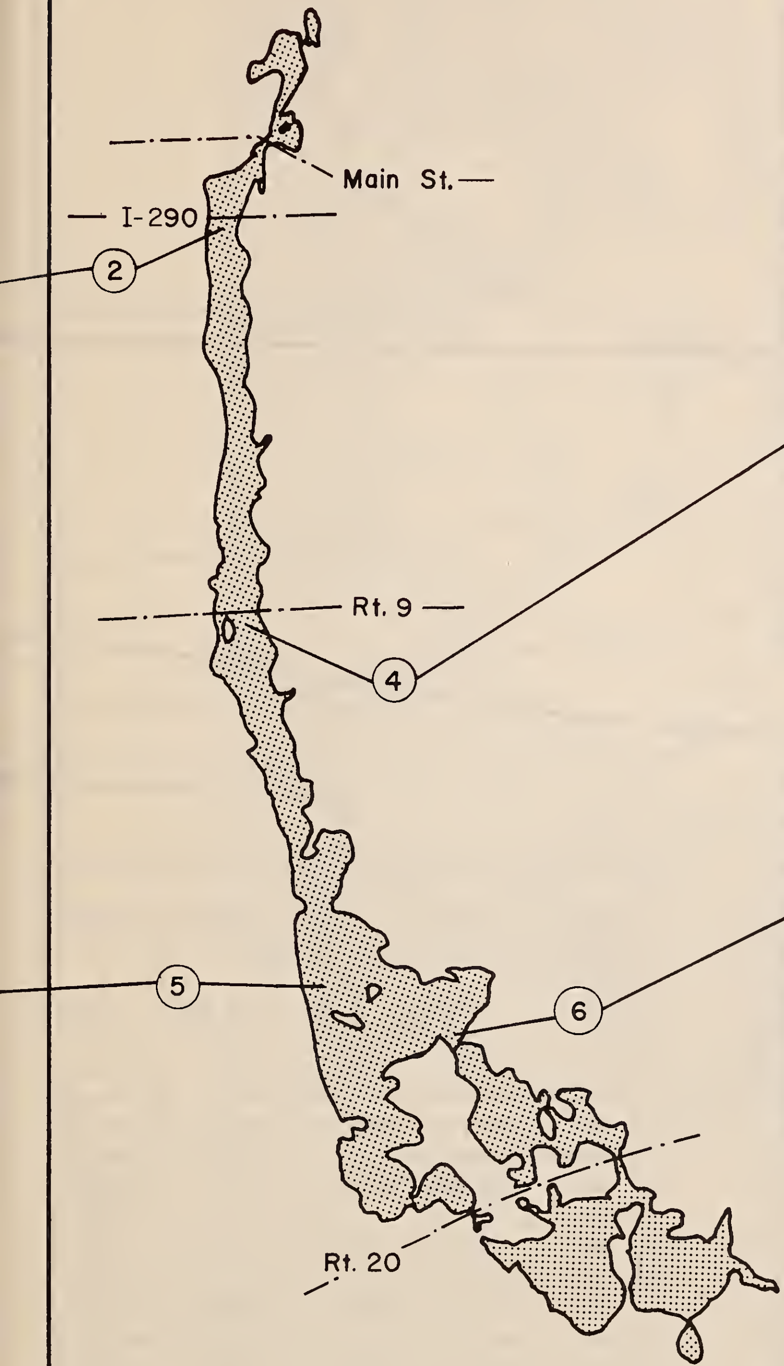
6. See reference (8)

7. - indicates data were not available or measured

Depth / Test	0"-3"	3"-6"	6"-9"	9"-12"	12"-15"
Hg	0.23	0.26	0.35	0.22	0.15
Cd	2.0	1.8	1.2	0.8	0.7
Pb	230.0	170.0	120.0	32.0	8.8
Zn	190.0	190.0	150.0	69.0	45.0
Ni	46.0	38.0	36.0	31.0	17.0
Cu	60.0	45.0	33.0	17.0	9.6
Cr	70.0	41.0	35.0	30.0	18.0
As	33.0	36.0	36.0	14.0	4.4
% Vol. Solids	7.6	9.7	14.8	19.4	30.6

Depth / Test	0"-5"	5"-10"	10"-15"	15"-70"	20"-
Hg	0.62	0.56	0.22	0.10	0.10
Cd	2.8	2.6	1.0	0.5	0.6
Pb	250.0	240.0	62.0	6.0	5.2
Zn	380.0	330.0	89.0	38.0	39.0
Ni	35.0	34.0	23.0	14.0	13.0
Cu	88.0	72.0	26.0	8.6	8.9
Cr	25.0	27.0	20.0	11.0	11.0
As	64.0	66.0	35.0	6.8	4.6
% Vol. Solids	19.2	19.5	33.2	23.7	24.5

Elememt concentrations in mg/kg (dry weight) for material passing a number 30 sieve.



Depth	0"-3"	3"-6"	6"-9"	9"-12"	12"-14"	14"-18"
Test						
Hg	0.38	0.38	0.65	0.15	0.18	0.13
Cd	1.7	1.4	1.2	0.5	0.5	0.8
Pb	220.0	190.0	180.0	29.0	7.2	7.0
Zn	200.0	200.0	200.0	61.0	47.0	39.0
Ni	27.0	24.0	46.0	33.0	15.0	15.0
Cu	72.0	68.0	60.0	30.0	9.1	9.3
Cr	24.0	20.0	31.0	20.0	15.0	15.0
As	43.0	46.0	79.0	20.8	13.0	11.2
% Vol. Solids	5.9	6.2	12.1	7.6	22.7	24.6

Depth	0"-5"	5"-10"	10"-15"	15"-20"	20"-24"	Bottom
Test						
Hg	0.38	0.22	0.10	0.08	0.21	0.17
Cd	2.3	0.7	0.2	0.1	1.5	1.8
Pb	150.0	10.0	3.5	1.7	9.8	10.0
Zn	300.0	65.0	24.0	22.0	110.0	100.0
Ni	38.0	15.0	6.6	5.7	55.0	46.0
Cu	54.0	12.0	4.8	3.9	38.0	31.0
Cr	26.0	9.0	5.6	4.5	17.0	15.0
As	17.4	24.3	6.6	2.6	33.2	28.1
% Vol. Solids	12.2	7.4	1.9	3.3	45.0	27.0

LAKE QUINSIGAMOND
CORE SAMPLES

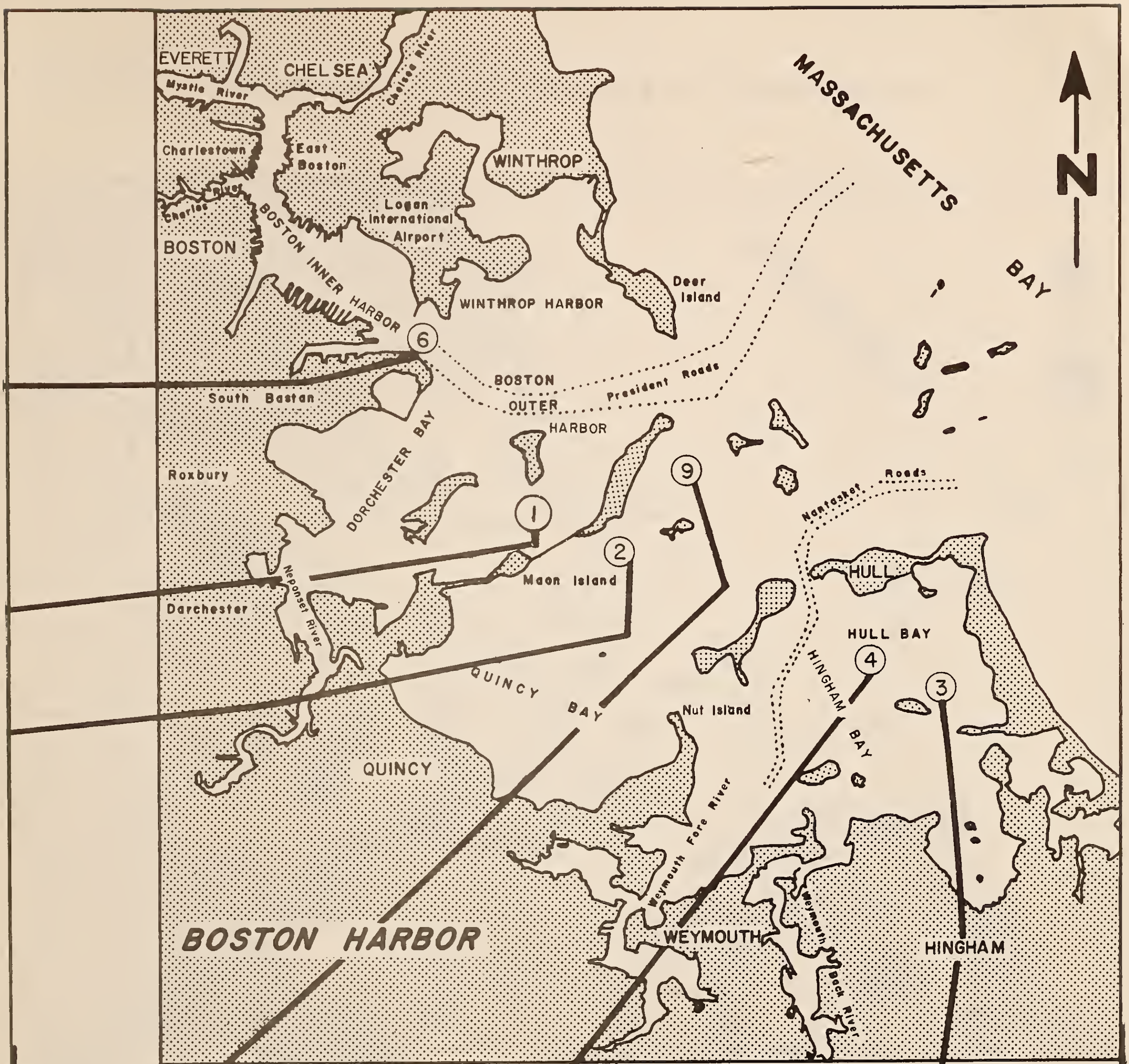
FIGURE I

Depth	0"-2"	2"-4"	4"-9"	9"-17"	17"-26"
Test Hg	0.14	0.16	0.90	1.10	0.8
Cd	0.7	0.9	1.7	2.1	3.4
Pb	23.0	180.0	1220.0	130.0	100.0
Zn	81.0	91.0	130.0	160.0	180.0
Ni	36.0	35.0	35.0	24.0	22.0
Cu	32.0	38.0	71.0	65.0	89.0
Cr	27.0	42.0	80.0	120.0	170.0
As	3.0	3.8	14.2	4.2	3.2
% Vol. Solids	3.9	4.5	8.2	6.0	6.3

Depth	0"-3"	3"-6"	6"-10.5"	10.5"-13"	13"-15"
Test Hg	3.0	2.0	0.4	2.3	0.84
Cd	6.1	2.2	0.8	2.9	0.8
Pb	200.0	110.0	26.0	120.0	54.0
Zn	350.0	170.0	60.0	150.0	74.0
Ni	33.0	22.0	11.0	22.0	15.0
Cu	180.0	89.0	30.0	97.0	39.0
Cr	160.0	76.0	28.0	85.0	33.0
As	2.4	4.4	2.0	4.0	2.0
% Vol. Solids	12.1	8.4	3.7	7.2	4.3

Depth	0"-3"	3"-7"	7"-10"	10"-12"
Test Hg	2.32	2.69	3.60	1.90
Cd	2.6	2.4	1.4	0.4
Pb	180.0	190.0	220.0	77.0
Zn	190.0	180.0	210.0	78.0
Ni	28.0	27.0	26.0	14.0
Cu	120.0	100.0	100.0	49.0
Cr	170.0	120.0	90.0	54.0
As	6.0	5.0	5.0	2.6
% Vol. Solids	9.2	9.2	8.3	5.6

Concentrations in mg/kg (dry weight) for material passing a number 30 sieve.



Depth	0"-2"	2"-6"	6"-11"
Test Hg	0.80	0.20	0.10
Cd	1.0	0.9	0.9
Pb	55.0	22.0	18.0
Zn	97.0	87.0	86.0
Ni	23.0	35.0	41.0
Cu	44.0	29.0	34.0
Cr	69.0	26.0	42.0
As	2.4	1.4	1.2
% Vol. Solids	4.0	3.6	3.6

Depth	0"-3"	3"-8"	8"-13"	13"-18.5"
Test Hg	0.15	0.19	0.14	0.62
Cd	0.7	0.8	0.8	1.4
Pb	7.2	8.4	16.0	50.0
Zn	51.0	55.0	53.0	88.0
Ni	17.0	20.0	21.0	18.0
Cu	16.0	19.0	17.0	35.0
Cr	25.0	26.0	23.0	35.0
As	4.0	3.4	3.6	3.0
% Vol. Solids	4.8	5.6	5.2	7.2

Depth	0"-3"	3"-17"	17"-26"	26"-32"
Test Hg	1.20	1.10	0.42	0.09
Cd	1.3	0.7	0.4	0.6
Pb	96.0	35.0	23.0	8.2
Zn	120.0	110.0	40.0	50.0
Ni	21.0	14.0	7.8	16.0
Cu	63.0	35.0	13.0	15.0
Cr	83.0	42.0	11.0	13.0
As	2.2	2.0	1.0	2.2
% Vol. Solids	7.2	10.5	2.7	6.8

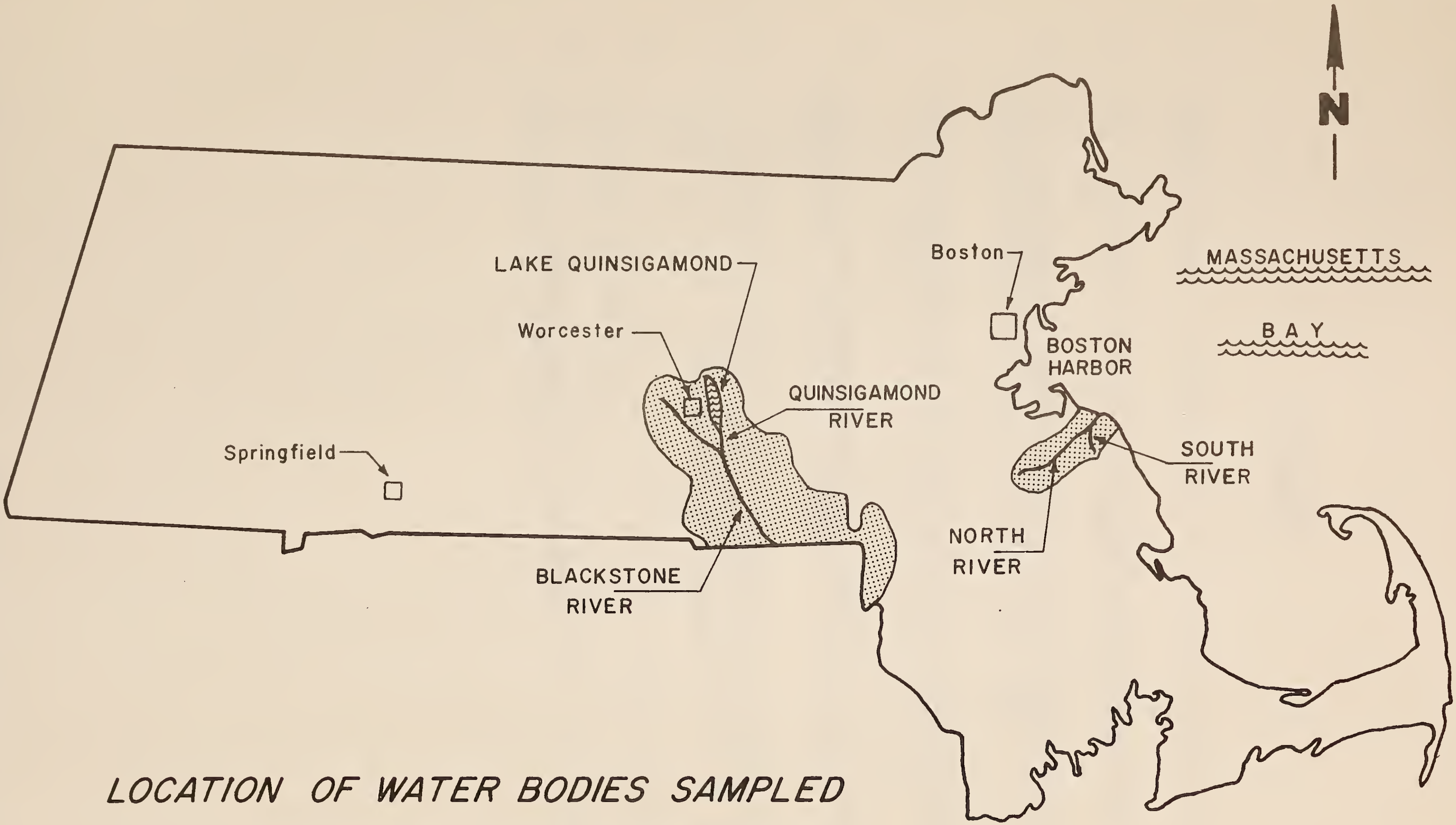
Mercury concentration* in the sediments of Boston Harbor.

BOSTON HARBOR
FIGURE 3

* mg/kg Dry Weight

Mean Concentration = 1.5 ppm

Standard Deviation = 0.87 ppm



LOCATION OF WATER BODIES SAMPLED AND REPORTED IN THIS PUBLICATION

FIGURE 4

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